Real Science

What it is, and what it means

John Ziman

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1.1 Defending a legend

Science is under attack. People are losing confidence in its powers. Pseudo-scientific beliefs thrive. Anti-science speakers win public debates. Industrial firms misuse technology. Legislators curb experiments. Governments slash research funding. Even fellow scholars are becoming sceptical of its claims[1].

And yet, opinion surveys regularly report large majorities in its favour. Science education expands at all levels. Writers and broadcasters enrich public understanding. Exciting discoveries and useful inventions flow out of the research laboratories. Vast research instruments are built at public expense. Science has never been so popular or influential.

This is not a contradiction. Science has always been under attack. It is still a newcomer to large areas of our culture. As it extends and becomes more deeply embedded, it touches upon issues where its competence is more doubtful, and opens itself more to well-based criticism. The claims of science are often highly questionable. Strenuous debate on particular points is not a symptom of disease: it signifies mental health and moral vigour.

Blanket hostility to 'science' is another matter. Taken literally, that would make no more sense than hostility to 'law', or 'art', or even to 'life' itself. What such an attitude really indicates is that certain general features of science are thought to be objectionable in principle, or unacceptable in practice. These features are deemed to be so essential to science as such that it is rejected as a whole – typically in favour of some other supposedly holistic system.

The arguments favouring 'anti-science' attitudes may well be misinformed, misconceived and mischievous. Nevertheless, they carry

surprising weight in society at large. Those of us who do not share these attitudes have a duty to combat them. But what are the grounds on which science should be defended?

Many supporters of science simply challenge the various specific objections put forward by various schools of anti-science. In doing so, however, they usually assume that the general features in dispute are, indeed, essential to science. They may agree, for example, that scientific knowledge is arcane and elitist, and then try to show that this need not be a serious disadvantage in practice[2]. The danger of this type of defence is that it accepts without question an analysis which may itself be deeply flawed. In many cases, the objectionable feature is incorrectly attributed to 'science', or is far from essential to it. Dogged defence of every feature of 'the Legend'[3] – the stereotype of science that idealizes its every aspect – is almost as damaging as the attack it is supposed to be fending off.

1.2 Science as it is and does

In the long run, science has to survive on its merits. It must be cherished for what it *is*, and what it can *do*. The moral basis for the defence of science must be a clear understanding of its nature and of its powers. One might have thought that this understanding was already widely shared, especially amongst working scientists. Unfortunately, this is not the case. Most people who have thought about this at all are aware that the notion of an all-conquering intellectual 'method' *is* just a legend. This legend has been shot full of holes, but they do not know how it can be repaired or replaced. They are full of doubt about past certainties, but full of uncertainty about what they ought now to believe.

A more up-to-date and convincing 'theory of science'[4] is required for a variety of other reasons. The place of science in society is not just a matter of personal preference or cultural tradition: it is a line item in the national budget. There are increasing tensions in the relationships between scientific and other forms of knowledge and action, such as technology, medicine, law and politics. Scientists are asked by their students whether they are being prepared for a vocation or for a profession. People are expected to make rational decisions arising from, and affecting, radical changes in the way in which science is organized and performed.

The uncertainties and confusions have not been dispelled by the sociologists who have displaced the philosophers from the centre of 'science

studies'. On the contrary, the various schools of sociological 'relativism' and 'constructivism' that have emerged in the past twenty years[5] often seem to be hostile to science, and eager to belittle its capabilities. In their enthusiasm to expose scientific pretensions to objectivity and truth, they exaggerate the genuine uncertainties and perplexities of scientific research[6], and propagate an equally false and damaging stereotype of pervasive cynicism and doubt. Despite repeated assertions that they too love science, and don't really dispute its practical claims, they thus confirm the natural scientists in their mistrust of the social sciences, and often seem to ally themselves with anti-scientific populism.

It must be emphasized, however, that this sceptical stance does not go unchallenged in the world of science studies. Many *metascientists* – that is, philosophers, sociologists, political scientists, economists, anthropologists and other scholars who study science as a human activity – have pointed out the weaknesses of this stance. They try to understand just what scientists think they are doing when they engage in research, and how much weight should be given to their results. They are interested in the way that scientists work, as individuals and as groups, and how this affects their findings. They may not accept scientific knowledge as uniquely true and real, but they do treat it as a peculiar human product worthy of special study.

These expeditions into the unknown heart of science branch out in all directions[7]. Metascientists make their observations through the intellectual instruments of many different disciplines, and analyse what they see along many different dimensions. The study of each such aspect has become a research specialty in its own right, with results that are often scarcely intelligible outside that specialty. We know much more about science nowadays than can be put together into a comprehensive, coherent image.

Metascientific pluralism is a wise recoil from overambitious attempts to encompass a complex human enterprise in a single formula. Nevertheless, these various modern accounts of science are not all disconnected. They start from the outside to explore the same range of ideas, activities and institutions, and they often come back with similar findings. In each case – that is the way that scholars work – they tend to put a personal interpretative spin on these findings. But one often discovers that essentially the same tale is being told by travellers who set out with quite different intellectual goals[8].

These findings are consistent with a relatively straightforward, if

sketchy, overall picture of what science is and does. In effect, a sociological dimension is introduced, not to replace the traditional philosophical dimension but to enlarge it. Ideas are seen as *cultural* elements as well as *cognitive* entities. *Individual* acts of observation and explanation are seen to gain their scientific meaning from *collective* processes of communication and public criticism[9]. The notion of a scientific 'method' is thus seen to extend outside the laboratory to a whole range of social practices. And so on.

This new picture of science is somewhat more complicated than the outmoded stereotype. It is not so sharply defined. It does not claim total competence. It treats human knowledge as a product of the natural world. It does not pretend to be impregnable against thorough-going scepticism or cynicism. It calls for more modesty and tolerance than scientists have customarily cultivated about themselves and their calling. But it does provide a stout intellectual and moral defence for science at the level of ordinary human affairs – the level at which nothing is absolute or eternal, but where we often forget that life is short, and feel passionately about pasts that we have not personally experienced, or plan conscientiously for the future welfare of people whom we shall never know.

1.3 A peculiar social institution

The most tangible aspect of science is that it is a *social institution*. It involves large numbers of specific people regularly performing specific actions which are consciously coordinated into larger schemes. Although research scientists often have a great deal of freedom in what they do and how they do it, their individual thoughts and actions only have *scientific* meaning in these larger schemes. Like many facts of life, this is so obvious that it was for long overlooked!

Science is one of a number of somewhat similar institutions, such as organized religion, law, the humanities and the fine arts. These institutions differ from one another in interesting ways. But what they all do – among many other things – is to produce quantities of *knowledge*. The peculiarity of science is that knowledge as such is deemed to be its principal product and purpose. This not only shapes its internal structure and its place in society. It also strongly colours the type of knowledge that it actually produces.

The sociological dimension is thus fundamental to our picture. But

the self-styled 'sociologists of scientific knowledge'[10] have become attached to a principle of 'symmetry' as between different forms of knowledge, and are mainly attracted to the features that science shares with other forms of social life. They have therefore largely ignored the procedures, practices, social roles, etc. that actually distinguish science from other institutions. Attention to these distinctive features does not mean that science is sacred. Scientific life would not be human if it were not permeated with folly, incompetence, self-interest, moral myopia, bureaucracy, anarchy and so on. It is no longer news that even the most high-minded institutions are depressingly alike in some of their less admirable characteristics. But it is only when we have understood the *differences* that make scientific knowledge unusual that we can appreciate the *similarities* that make it ordinary.

This may seem a rather obvious point, but it needs firm emphasis[11]. Sociologists who deliberately 'bracket out' the distinctive institutional characteristics of science inevitably arrive at an extreme version of cultural relativism [*8.13*, *10.4*]. This, in turn, generates a sceptical quagmire that blocks every path towards revision of the traditional Legend. They really have no reason to deny the plain evidence of our senses that science *does* have a number of unmistakable social features which should surely figure in our picture of it.

1.4 A body of knowledge

Science generates *knowledge*. The actual observations, data, concepts, diagrams, theories, etc., etc. that make up this knowledge often appear in tangible forms, as written texts, maps, computer files and so on. Some of it is also very well founded, and no more questionable in practice than the warmth of the sun or the solidity of the ground under one's feet. But there are many forms of knowledge[12], so what makes any particular form of it *scientific*? And if it *is* scientific, how firmly should we *believe* in it?

Until recently, the answers to such questions were considered entirely a matter for philosophy. Scientific knowledge was thought to be no more than a carefully edited version of aggregated reports of innumerable independent explorations of the natural world. What made these explorations 'scientific' was their particular subject matter, and the particular way in which they were carried out. The main project of philosophers of science was to define the general principles of *demarcation* between scientific and non-scientific knowledge[13]. They could then show – it was

hoped – that knowledge fully satisfying these principles was – or would be – worthy of complete belief. In the heyday of the Legend it was even argued that the idea of 'non-scientific knowledge' was a contradiction in terms, as if there were no other reality than the world revealed by science.

The failure of this project[14] has not taken these questions off the metascientific agenda. Our picture of science is still heavily impregnated with *epistemology* – that is, the 'theory' of knowledge. What is now clear is that fundamental epistemological issues cannot be resolved by an appeal to abstract general principles. For example, as we have already noted, scientific activity involves *social* factors operating far outside the normal scope of philosophy[15].

Metascientists are also beginning to realize that it is not feasible to separate 'knowledge' from acts of 'knowing'. Scientific knowledge is not just a disembodied stream of data or the books on a library shelf. It is generated and received, regenerated or revised, communicated and interpreted, by human *minds*. Human mental capabilities are remarkable, but also limited. They are also closely adapted to the *cultures* in which they operate. Many of the characteristic features of science are shaped by the psychological machinery that scientists employ, individually and collectively, in their study of the world. In other words, *cognition* is the vital link between the social and epistemic dimensions of science.

The appearance of cognitive factors in our picture is a decisive break with the Legend. Philosophers of science have always steered clear of 'psychologism', for fear that it would rob science of its much-prized objectivity. Personal judgements of fact or meaning might well be required to make discoveries, but they were bound to introduce irrational elements which would have to be systematically excluded from the final analysis.

Fortunately, modern cognitive science is not completely clouded over with subjectivity. Human minds are all different, but they are built to the same general plan, and acquire common standards from the scientific culture of their research discipline. For many purposes they are just as alike as many artificial instruments of perception, calculation and communication. In practice, the *social stability* of scientific knowledge is a reasonable indicator of its objectivity.

1.5 Naturalism in the study of Nature

Our new picture of science thus draws on a very wide range of academic disciplines. Conventional philosophical questions about what is to be

believed have to be combined with the sociological analysis of communities of believers. Perception, cognition and language all play their part. Even the humanistic concept of *empathy* – the capacity to enter into the thoughts and feelings of another person – has its place in the social and behavioural sciences [*5.11*]. A philosophy *of* science does not have to encompass all that might be required of a general philosophy *for* science[16], but it still involves many elements drawn from wider accounts of the human condition.

The involvement of so many disciplines does not merely complicate the picture. It also means that we are taking a *naturalistic* point of view[17]. By including 'scientific' concepts in our overall picture of science itself, we are assuming that it too is 'natural', in the sense of being susceptible to description and explanation by the same methods, and according to the same criteria, as other features of the natural world – including human society.

To be consistent with other forms of knowledge, epistemological naturalism has to be *evolutionary*[18]. Modern science is seen as the heir to an unbroken lineage of knowledge-acquiring organic forms, stretching back to the beginnings of life on earth [*9.7, 10.3*]. This is a useful unifying principle for what sometimes seems no more than 'a cluster of symbols, languages, orientations, institutions and practices, ways of seeing etc.'[19]. It recognizes that many of the peculiarities of science are historical survivals rather than current necessities, and accepts that the institution as a whole is bound to change over time.

Epistemological naturalism also emphasizes the *dynamism* of science. Even the knowledge it generates is continually changing. The noun 'science' is closely identified with the verb 'to research', indicating that it is an active *process*. At any given moment, this process involves the coordinated actions of many quasi-permanent entities, such as research scientists, research instruments, research institutions, research journals etc. By its very nature, science is a complex *system*[20]. It cannot be understood without an explanation of the way that its various elements *interact*.

A naturalistic 'picture' of a dynamic system is a *model* [*6.10*]. Although this word means no more than a simplified representation of a complex entity, and is often used very loosely to mean any abstract theory, it conveys intuitive notions of internal structures and mechanisms. In ordinary scientific usage, a theoretical model can be taken apart conceptually, and then put together again to make a working whole. Meaningful theoretical questions can then be asked about the functioning of the various parts, and the consequences of specific changes in their make up or interactions.

Such questions are not just theoretical; they arise continually out of practical issues in the real world – issues that are often in dispute between the defenders of science and its opponents. Has our understanding of nature been influenced by the gender-specific cognitive capabilities of predominantly male researchers? Does peer review quench scientific creativity? What scientific weight should be attached to a single, carefully recorded, but unconfirmed observation? To deal with questions of this kind we need more than a new 'theory' or 'picture'. This book is about the new *model* of science that is required to replace the stereotype of the Legend.

1.6 Keeping it simple

Naturalism, as such, is not enough to hold our model together. It merely affirms that scientific research is not essentially distinct from the many other ways in which we humans typically get to know about 'life, the universe, and everything'. In principle, we should be taking a holistic view that covers 'the whole picture'. In practice, each discipline may still look at only one particular aspect of this picture, and report what it sees in its own particular language.

The fact is, quite simply, that the barriers of comprehension between these languages are so high that a *transdisciplinary* viewpoint is required to transcend them. It is all too easy to be mentally trapped in a particular discipline, unable to cross the conceptual Divide into other modes of thought. This is a familiar situation in the natural sciences. What, for example, is a 'gene'? Is it a heritable trait, as seen by the geneticist? Is it a segment of DNA, as seen by the molecular biologist? Is it a protein factory, as seen by the biochemist? Is it a developmental switch, as seen by the embryologist? Is it even, perhaps, an active, utterly selfish being, as depicted by some evolutionists? It takes the general standpoint of the biologist to see these diverse concepts as different aspects of the same entity.

Similarly, if we were to begin our metascientific explorations deep in the realm of sociology, and insist, for example, that science has to be thought of primarily as a *heterogeneous actor network*[21], we would find it very difficult to accept that it is also, in some ways, a *sequence of refutable conjectures*[22], or a *bundle of research traditions*[23], or a *problem-solving, computational algorithm*[24]. Corresponding difficulties would arise if we were start from inside any other well-established discipline. Yet valuable insights

have come from each of these specialized points of view. The trouble is that, although the academic languages in which they are expressed are not necessarily 'incommensurable'[25], they have evolved independently to answer very different types of question. A great deal of intellectual boundary work is needed to translate ideas directly from one such specialized language to another and to make them consistent and coherent.

It is much more profitable to *start* looking at science from a standpoint where it can be seen and depicted – however indistinctly – as a whole. The great merit of naturalism is that it automatically takes just such a standpoint. Educated citizens of economically advanced countries know that there is 'a thing called science'[26], and can say quite a lot about it. In response to detailed questioning, they might say that it is 'a body of knowledge', or 'an organised social activity', or 'a way of life for certain people', or 'a heavy burden on the taxpayer', or 'a power for good and/or evil'. Although these answers would be very diverse, and often contradictory, they would all be based upon a shared understanding of a simple truth – that these are indeed only different aspects of a *single entity*, of whose existence they are as sure as of death and taxes.

This 'natural ontological attitude'[27] is largely tacit. Its power resides in everyday usage. It implies, and is implied by, the way in which we ordinarily talk. A familiar word such as 'scientist', 'experiment', 'research', 'apparatus', 'scientific paper', etc. can carry a whole raft of formal meanings. It may well be defined quite differently in different contexts. But in each context it is understood to refer to the same discernible element, or feature of the world. Such words thus act as mental bridges re-uniting the various aspects or dimensions into which a natural entity may have been analysed. In saying, for example, that 'science involves experiments', we are not really bothered by the fact that the philosopher's concept of an experiment as, say, 'an attempt to refute a hypothesis', seems quite remote from the economist's characterization of it as 'a speculative investment whose ultimate rent may be difficult to appropriate'. We simply rely on our practical knowledge that these are just two different ways of looking closely at the same type of activity.

Many scholars abhor the fuzziness and ambiguity of the 'natural language' used by 'lay persons'. Their ideal would seem to be a precise, unambiguous, quite general *metascientific language* into which all the results obtained by different disciplines could be accurately translated, without fear or favour. But this is an unattainable goal [6.6], even for the representation of a much less complex entity than modern science.

Failing that, they prefer to concentrate on enlarging and perfecting their own particular domain, perhaps hoping that its specialized viewpoint could eventually be widened to take in the whole scene.

This is a perfectly reasonable preference. In science studies, as in other scholarly enterprises, progress is made largely by narrowly focussed research [*8.3*]. I am not in any way suggesting that this research is invalid or inappropriate. Nor am I insisting that its results are irrelevant unless they can be expressed in non-specialist terms. The true strength of a discipline often resides in a highly specialized framework of concepts [*8.4*] which can only be mastered by a lengthy effort.

But the purpose of this book is not to review in detail the work of scholars in these various specialties: it is to derive from their work a model of science that can be understood and accepted by a much wider public. This model has to be presented in terms that are equally widely shared. To start with, these terms must already be 'common knowledge' – that is, they cannot be much more sophisticated than the words and concepts that people ordinarily use when talking about science.

At first sight, this would seem to make everything unacceptably vague. Take, for example, the very word 'knowledge'. What does it mean to say that we 'know' something? Does it convey broadly that we are 'familiar with it', or 'have been informed of it', or does it imply well-founded conviction, if not complete and justifiable certainty? As any good dictionary will show, ordinary English usage covers a whole range of meanings, often in closed circles of reciprocal definition. But what would be gained here by trying to define 'knowledge' more precisely? Not only would it pre-empt the whole issue of scientific credibility; it would also rob us of a general word for a familiar human capability.

The incorporation of bodily experiences into mental traces is a primary feature of our very existence. By referring to it in ordinary lay terms we show that we understand that 'knowing' is a 'fact of life', and as such is a major functional module in our model of science. As a natural process it certainly demand systematic analysis. But the main argument would not be made more definite if we took this module apart and reduced it formally to more basic elements which were less familiar but really just as vague [*10.8*]. Admittedly, it doesn't have an adjectival form; but in using the philosopher's word 'epistemic' I simply mean 'relating to knowledge' in the same everyday sense.

Let me emphasize, however, that the new model is not already latent in 'folk discourse', just waiting to be developed like a photographic

image. It is not even widely accepted in the world of science studies, although I believe that it is now beginning to take shape in the minds of certain other scholars there. To put this model together I have had to enter quite deeply into various specialized disciplines, select what seemed to be relevant conceptual material, translate this material roughly into lay terms, and trim the various bits and pieces into an untidy fit.

No earnest scholar in any of these disciplines will be satisfied by such a patchwork of heterogeneous concepts. I must surely have missed out, misunderstood, or misrepresented innumerable points that are deemed to be crucial in each particular domain. But this book does not have to be 'academically correct'. It is addressed to a more general audience, including a great many people who have had first-hand experience of scientific life and work. They will reject elaborate or esoteric interpretations of scientific activity that seem remote from this experience. Their acceptance is the real test both of the adequacy of the model and of the intelligibility of my account of it[28].

To sum up: I could not say what I wanted to say in this book *except* in the most direct and simple 'lay language'. This is not just because most people would not otherwise be able to understand it, nor because scientists would not otherwise recognize themselves in it. It is also because this is the only language in which 'science' stands for a many-sided natural entity, and in which there is a consistent terminology for describing all its aspects.